CHEMICAL LEACHING
IN LARGE CONVENTIONAL AND NO-TILLAGE SOIL COLUMNS

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INTRODUCTION

No-tillage and other conservation tillage systems are very effective in reducing erosion, in part because macropores consisting of cracks, root channels, and worm and insect burrows can speed the flow of water through the root zone. Macropores may also lead to faster movement of nitrates and pesticides through surface horizons under no-tillage, with the potential to contaminate shallow groundwater in Georgia. Our objectives were to compare macroporosity in conventional and no-tillage soils from Georgia, and to determine the effect of the initial rainfall on chemical leaching in these soils.

METHODS

Large columns of soil were taken from a 14 year-old tillage experiment at Griffin, Ga consisting of 4 plots each of conventional (CT) and no-tillage (NT). A double-cropping system of soybeans and winter wheat in rotation with grain sorghum and crimson clover had been grown on these plots (Tollner et al., 1984; Radcliffe et al., 1988). The soil was a Cecil sandy clay loam. PVC cylinders, 30 cm in diameter and 50 cm in length were pressed into the soil to a depth of approximately 45 cm using a back-hoe. The columns were then dug out and taken to the laboratory for further study. Eight cores (one from each plot) were taken in May of 1989 for a dye study. Sixteen columns (two from each plot) were taken in February of 1990 for a chemical leaching study. In the second set of columns, the interior surface of the PVC cylinders were coated with grease to prevent water flow between the cylinder and the soil cores.

In the first study, a dye was used to trace the path of water movement. Three hundred g of ultramarine blue dye was applied in powder form to the surface of each core and water was then applied using a spray nozzle at a rate of 4.5 cm h^{-1} for one hour. The cores were allowed to drain for 1 week and then one core from each tillage was split along the vertical axis and 3 cores from each tillage were cut along the horizontal axis in 5 cm segments. The cores were photographed and image analysis was used to determine the percent of the cross-sectional area that was stained.

In the second study, chloride was used as a non-adsorbed tracer to simulate the leaching of nitrate. All the cores were prewetted by adding 16 cm of water to the surface of the cores using a spray nozzle. Background chloride concentrations were measured in the leachate of each column at this time. Pottasium chloride (KCl) was applied in powder form at a rate equivalent to 300 Kg ha^{-1}. On half of the columns (4 NT and 4 CT), a small rainfall event immediately after application was simulated by applying 0.9 cm of water with the spray nozzle. The other columns did not recieve such a rain. One week later, a large rainfall event was simulated on all columns by applying approximately 16 cm of water with the spray nozzle at a rate of 4.5 cm h^{-1}. Leachate was collected from the bottom of the cores in 10 minute intervals and analyzed for Cl using an ion specific electrode. Mean background Cl concentrations, determined earlier for each column, were subtracted from the measured leachate concentrations. One column from each of the CT treatments (with and without initial rainfall event) was excluded from the analysis because of irregularities in the water application rate.

RESULTS

In CT columns, the dye moved as a front to a depth of about 5 cm and there was no dye found below 10 cm, indicating no macropore movement (Table 1). In the NT columns, there was extensive evidence of macropore movement in that the dye moved in an irregular pattern and much deeper. Macropores appeared to decrease in number with depth, but some penetrated to the bottom of the NT columns (over 40 cm).

TABLE 1. Mean Percentage of Horizontal Cross-sectional Area Stained by Dye in CT and NT at 5 Depths.

Depth of Cut (cm)	Area Stained (%) CT	NT
5	99.3	15.7
10	0.4	15.4
15	0.0	10.0
20	0.0	4.1
25	0.0	0.7

When the columns did not recieve a small initial rainfall event, there was considerable difference between tillages in the leachate Cl concentrations (Fig. 1 top). Early in the event, Cl concentrations were higher in NT (the peak concentration occuring at about 40 min) because macropores provided a rapid path for Cl movement. Later in the event, Cl concentrations were higher in CT because the smaller average pore size caused a delay in the arrival of the peak concentration (after about 100 min). In addition, the curve for CT showed a higher and more narrow peak compared to NT. This is because there was a more narrow range of pore sizes in CT causing the Cl pulse traveling in the various pores to arrive at the bottom of the column at nearly the same time. In NT, macropores created a wider range of pore sizes and caused the Cl pulse to be more spread out.

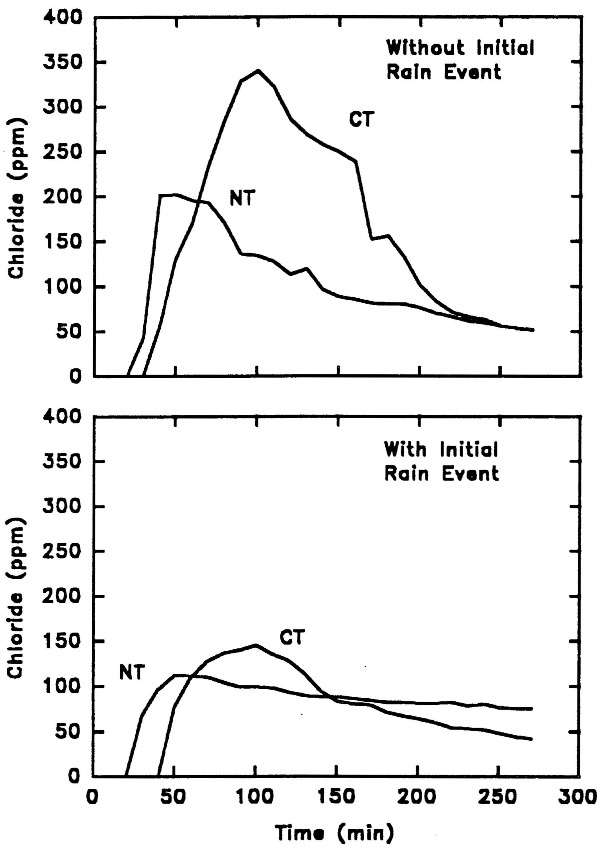

Figure 1. Leachate Concentration During Simulated 16 cm Event in NT and CT, Without Initial 0.9 cm Event (top), and With Initial 0.9 cm Event (bottom).

When the columns received a small initial rainfall event (Fig.1 bottom), there was little difference between tillages and Cl concentrations were reduced by about half, compared to leaching in the absence of the small initial event (Fig. 1 top). The reduction in leaching can be explained in terms of the two region model of Van Genuchten and Wierenga (1976).

They proposed that most natural soils consist of dynamic and stagnant regions of water movement. The stagnant regions correspond to the interiors of aggregates and peds where pore sizes are so small that water movement is essentially zero. The dynamic regions correspond to the exteriors of aggregates and peds and the void spaces between these, including macropores. Chemicals can move by mass flow with the water in the dynamic region, but movement into the stagnant regions occurs by diffusion only, which is usually slow compared to mass flow.

The small rain immediately after KCl application carried the Cl a short distance into the soil columns. During the week-long interval that followed, some of the Cl diffused into the stagnant regions in the interiors of aggregates and peds. When the large event occurred, much of the Cl in the stagnant regions could not diffuse out to the dynamic regions in time to be carried away. As a result, more Cl remained in the soil and leachate concentrations were lower, compared to the treatments without an initial rain event.

The fact that a small initial rain reduced leachate concentrations in both tillages indicates that stagnant regions occur in CT soils (as well as NT soils), even in the absence of macropores. The similarity in leachate curves for both tillages indicates that macropores are not as important when much of the chemical is contained in stagnant regions.

SUMMARY

Macropores can be expected to be more common in long-term NT soils compared to CT soils. In our study, macropores constituted 1-15% of the volume in the top 45 cm of NT soil and decreased in number with depth. Rapid leaching of surface applied chemicals can occur in NT if a large rainfall event follows application. If a small rainfall event follows application, then there may be little difference in leaching between NT and CT in subsequent events. Stagnant regions of soil in both NT and CT act as sinks for chemicals and, under the right conditions, can reduce leaching.

LITERATURE CITED

Radcliffe, D. E., E. W. Tollner, W. L. Hargrove, R. L. Clark, and M. H. Golabi. 1988. Effect of tillage practices on infiltration and soil strength of a typic Hapludult soil after ten years. Soil Sci. Soc. Am. J. 52:798-804.

Tollner, E. W., W. L. Hargrove, and G. W. Langdale. 1984. Influence of conventional and no-tillage practices on soil physical properties in the Southern Piedmont. J. Soil Water Conserv. 39:73-76.

Van Genuchten, M. Th. and P. J. Wierenga. 1976. Mass transfer studies in sorbing porous media: I. Analytical solutions. Soil Sci. Soc. Am. J. 40:473-479.